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NATIONAL GEODESY—STATUS AND PLANNING

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SURVEYING AND MAPPING DIVISION

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PAPERS

NATIONAL GEODESY—STATUS AND PLANNING

By Leo Otis Colbert,[1] M. ASCE

Synopsis

From its earliest beginning the United States Coast and Geodetic Survey has been engaged in establishing a federal geodetic framework of horizontal and vertical control as a prerequisite to national mapping and as a base for land surveys and engineering projects. This paper describes the development of the geodetic network in the United States, the present status of control surveys, the planning of future geodetic surveys, and the part that engineers can play in helping to preserve the many thousands of monumented stations and bench marks that have been established.

Introduction

The activities of the Coast and Geodetic Survey of the United States Department of Commerce date back to the early part of the nineteenth century when maritime nations generally began to recognize the wisdom of systematically surveying and charting their coastal waters.

In those days the United States was concentrated along the Atlantic coastal plain. Fisheries and shipbuilding were important industries, and water-borne commerce was the medium for the movement and exchange of products between the various states and with foreign countries. The promotion of that commerce was the prime reason for the passage of a resolution by Congress, in 1807, directing the President of the United States to order a survey of the coast and the outlying islands and fishing banks. President Thomas Jefferson asked the advice of the American Philosophical Society, the foremost scientific body of the day, as to how the survey should be undertaken. Although the task assigned was a practical one, he intended that the survey should follow scientific principles that would stand the test of time. Various plans were discussed. The plan submitted by Ferdinand Hassler was adopted,

Note.—Written comments are invited for publication; the last discussion should be submitted by September, 1951.

[1] Rear Admiral (*Retired*); formerly Director, U. S. Coast and Geodetic Survey, Washington, D. C.

and he was named the first director of the survey operations. As a scientist, and as one of the originators of the Geodetic Survey of Switzerland, Mr. Hassler knew the importance of building on a permanent scientific foundation, no matter how urgent the need for quick results. It is to his lasting credit that he did not allow himself to be stampeded into haphazard decisions. Had he planned to meet only the limited needs of his time, his work would have had to be done over at great expense in later years. From the very beginning, Mr. Hassler insisted that the surveys of harbors and coastal areas of the United States should be controlled by a backbone of geodetic measurements. His work had the foundation of accuracy adequate to satisfy future needs.

As the United States grew, the work of the Coast and Geodetic Survey was extended to the Pacific and Gulf coasts. In 1871, Congress authorized a geodetic connection to be made between the Atlantic and Pacific coasts, and charged the Coast Survey with the duty of providing the states with geographic positions and bench marks for the control of their topographic and geologic mapping. Since that time, it has been actively engaged in extending triangulation and precise levels in the interior of the United States for the purpose of establishing a federal framework on which all land surveys and engineering projects could be based.

Geodetic control surveys are necessary in connection with regional development programs so that the various aspects of topography may be correctly mapped and adequate studies of physical characteristics may be made in relation to the area as a whole. Without such control, gaps or overlaps occur between contiguous local surveys, and errors of considerable magnitude may result.

In the national mapping program, close cooperation exists between the Coast and Geodetic Survey and the Geological Survey of the United States Department of the Interior. The work of the former in providing the fundamental framework of horizontal and vertical control for the United States is planned to correlate with a comprehensive program, and priority is given when needed to areas where topographic surveys are proposed.

Horizontal Control

To span the continent from coast to coast and from north to south, widely spaced arcs of triangulation were first established—giving a preliminary framework. Intermediate arcs, spaced from 40 miles to 60 miles apart, provided control for boundary determinations and met the general needs of the various states. The next logical step has been followed, in the decade from 1940 to 1950, by filling in between arcs with area triangulation, which has been adopted to obtain uniform coverage in the area and to secure consistency in the results. Positions determined by such area triangulation are located accurately with reference to points in all directions, and consequently they tie into the previously observed arcs. The observations of area triangulation are given a final simultaneous adjustment within each 40-mile to 60-mile square.

To insure adequate agreement among the component parts of the triangulation, basic criteria are adopted for the observations. In first-order work the

average triangle closure must not exceed 1 sec; and the final length, when carried throughout the chain of triangles from one measured base to another, must agree on an average of about 1 part in 75,000.

At least one triangulation station is being established in each 7½-min topographic quadrangle. Stations at 4-mile intervals are being provided along the main highways in agricultural areas and closer spacing is used in metropolitan areas. To coordinate local urban surveys, at least one federal base is measured in metropolitan areas of 100,000 population or more.

In July, 1949, there were more than 110,000 miles of arcs of first-order triangulation and second-order triangulation in the United States, with monumented stations established at an average of about 10 miles along the various arcs. Geographic positions (that is, latitude, longitude, and azimuth) have been determined for about 150,000 stations consisting of monumented points and prominent objects, such as water tanks, church spires, cupolas, chimneys, etc. To facilitate the use of the national network a near-by azimuth mark is established at each monumented station to furnish the local engineer and surveyor with directional control for local surveys without the necessity of establishing a true meridian line.

Vertical Control

Another phase of geodetic operations is the precise leveling for the determination of elevations of bench marks above mean sea level. In the distribution of the vertical control of the United States, the Coast and Geodetic Survey followed a program starting with widely spaced lines 100 miles apart, supplemented by lines spaced 50 miles apart. The present program provides for area leveling in which lines spaced not more than 6 miles apart are connected to the wider spaced lines in a consistent network of levels. Bench marks are set at 1-mile intervals along each line. For convenience in running and in the subsequent use of the bench marks, the lines of leveling follow the routes of highways and railroad systems. In July, 1949, there were more than 360,000 miles of first-order leveling and second-order leveling in the United States, and upward of 275,000 established bench marks.

Programming Future Geodetic Operations

During the past several years geodetic control has been established in some of the larger river basins and valleys—the most prominent of which are the Columbia River Basin and the Missouri River Valley—in anticipation of multiple water-use projects to be undertaken in these areas, namely, reclamation, navigation, and flood control. These projects must consider a river system as an integrated whole and require planning on an extensive area basis. Comprehensive horizontal and vertical control surveys should precede the planning stage to coordinate detailed maps of the river basins, dam sites, and reservoir locations. Local surveys based on geodetic control enable conclusive studies to be made of alternate sites with a view to selecting the most economical and efficient ones. In the final work, local construction surveys will be based on the geodetic control monuments.

Close contact is maintained with federal, state, county, and municipal organizations that use control surveys. An effort is made to plan field work to meet their most urgent needs. At the present time the demand is three times that which can be provided with the funds available. Under such conditions, only projects of the highest priority can be undertaken. This is by no means a satisfactory arrangement from the standpoint of the agencies whose programs may have to be postponed.

Geodetic Surveys Outside Continental United States

The extension of geodetic control surveys into the heart of Alaska is one of the formidable tasks that face the Survey engineers. In isolated regions, frequently with temperatures below zero, many difficult problems are encountered, not the least of which is the problem of logistics. Careful advance planning is required to insure that necessary supplies and replacements are on hand when needed.

Alaska is now tied to the continental United States by continuous arcs of triangulation that extend from Puget Sound through southeast Alaska and along the Alaska Highway through Canada and Alaska to Cape Prince of Wales and the Little Diomede Island in Bering Strait. There is an extenisve spur along the Alaska Peninsula, which continues through the Aleutian Islands to Adak, Kiska, and Attu.

Triangulation surveys are now in progress in western Alaska and along the Arctic coast. At about 5-mile intervals along this northern coast, stations between first-order accuracy and second-order accuracy will be established. Trigonometric leveling is being carried on concurrently, and elevations and positions are being determined for the numerous peaks in the extensive mountain ranges of northern Alaska. In the summer of 1949, four parties were engaged on these surveys. Transportation for these parties was furnished by wheel and float planes, helicopters, amphibious tractors, and various types of floating equipment.

The ultimate goal of the geodetic work in Alaska, apart from furnishing control for the survey of the water areas, is the establishment of the network in the interior. Only when this network is complete will it be possible to provide large-scale mapping and to explore fully the commercial, industrial, and strategic possibilities of Alaska.

In the Hawaiian Islands, the Coast and Geodetic Survey and the Territorial Survey Office are cooperating on a geodetic project of significance—the reconstitution and extension of horizontal control. The program contemplates the reestablishment of marks and monuments destroyed or uprooted during World War II in the haste of large-scale defensive preparation. The new work will provide a more comprehensive scheme with closer spacing of monuments for use in mapping and for land boundary determination.

Office Adjustments of Geodetic Control

Field surveys are but one phase of national geodesy. If the instruments were perfect, if there were no refraction or bending of light rays, if there were no

personal equations, and if exact pointings and observations were always made, there would be no discrepancies in the triangulation or the leveling observations. The surveys would have no errors of closure, the triangulation lengths and directions would agree whenever they met, and the level lines would check between loops.

Of course, these conditions do not exist. Small discrepancies develop which by themselves may be tolerated, but which in the aggregate must be eliminated by mathematical treatment so that all parts of the triangulation and leveling are in harmony. About seventy mathematicians in the Washington (D. C.) and New York (N. Y.) offices are engaged in making these computations and adjustments, some of which require the solution of as many as three hundred simultaneous equations.

To meet the impact of modern requirements on this work, together with the complexities that result from the expanded geodetic program, a study of punch-card methods of computation was made. After developing particular techniques for processing the field data, some high-speed calculating machines were installed. After a 2-year trial, these were found to be particularly applicable to the adjustment of extensive triangulation networks. These machines save many man-hours and relieve the personnel of much of the strain characteristic of this work.

Final results of the observations of the triangulation and traverse surveys of the Coast and Geodetic Survey are computed on two different systems of coordinates—geographic and rectangular. Geographic coordinates are expressed in terms of latitudes and longitudes. Such cooridnates have the advantage that they constitute a universal system, and any point on the earth is directly related to any other point.

For surveys of limited extent, the system of "State Plane Coordinates," devised by the Survey, has a distinct advantage in that it gives a method of connecting local surveys to the national network of control by the usual methods of plane surveying, with which all engineers and suveyors are familiar.

To encourage wider use of the national network and to facilitate procurement of information, two series of state maps are published, one for triangulation data and the other for leveling data. The scales are large enough (about 1:650,000) to show graphically each station in the existing scheme of first-order triangulation and traverse and of second-order triangulation and traverse and to indicate the locations of supplemental and intersectional triangulation stations. All lines of levels are shown. These maps are available on request to the Washington office.

Cooperation of Engineers

The cooperation of engineers is solicited to help preserve the many thousands of triangulation monuments and bench marks that have been established throughout the United States. These survey monuments, which are usually bronze disks, set in concrete or bedrock, are the visible results of the field surveys. They are useful only in so far as they can be recovered. For the first few years after their establishment they can usually be found quite readily. After the lapse of a few years, however, features of the surrounding terrain may have changed, making it difficult to find the monuments from the original

descriptions. Engineers and surveyors who visit or use these monuments, and who find that their descriptions need modification, will do a public service by notifying the Coast and Geodetic Survey of present conditions, revising the descriptions as necessary.

New construction and improvements (particularly on highways), which sometimes mean disturbance of survey monuments, also contribute to this problem. Notification should be made by the local engineer as soon as it becomes known that a survey mark must be moved, or will be destroyed, when construction actually gets under way. In most cases, a replacement station can be established by the engineer or surveyor, and instructions will be forwarded on the methods to be followed in order that the requisite accuracy may be retained.

Conclusion

It is in the best public interest to have all surveys—no matter how localized—tied in with the national network of geodetic control. The extent to which this ideal is reached will depend largely on the availability of control points, and on their use. Triangulation stations and bench marks must be brought within the reach of the local surveyor and engineer.

Although substantial progress has been made in providing basic control data for the United States, the job is far from complete. Accurate control surveys must be provided at an accelerated rate, so that the program of national geodesy will be able to keep abreast of the expanding engineering requirements of commerce and industry.

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